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(54) **Display device and method of manufacturing such a device.**

(57) The response rate of a liquid crystal display device is increased in that capacitive variations in the liquid crystal mixture caused by a different drive voltage or varying capacitances in drive transistors are taken into account in advance. If necessary, the required corrections are performed with a microprocessor, but they are preferably stored in advance in a look-up table.

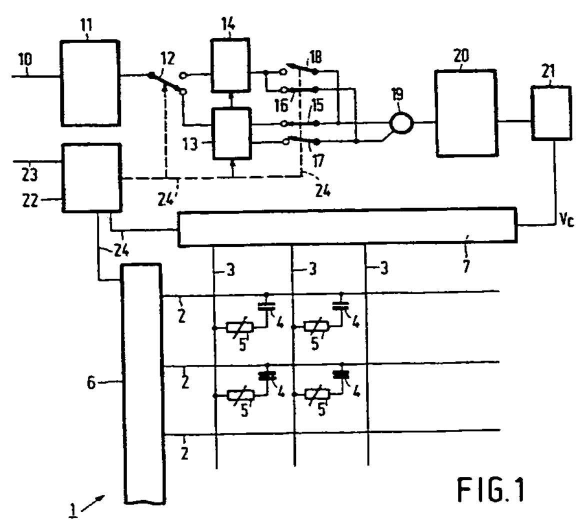

FIG.1

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The invention relates to a display device comprising an electro-optical medium between two supporting plates, provided with a system of pixels arranged in rows and columns, provided with means for providing row and column connections with such voltages, that column connections are provided with column voltages during at least a part of a selection period in which rows are selected *via* drive elements.

More generally, the invention relates to a display device comprising at least one pixel with an electro-optical medium between picture electrodes defining the pixel and a drive unit for applying drive voltages to the electrodes.

The invention also relates to a method of manufacturing a display device comprising a system of pixels with an electro-optical medium between electrodes defining pixels and a drive unit for applying drive voltages to the electrodes.

The invention also relates to a device for adjusting such a drive unit.

A display device of this type is suitable for displaying alpha-numerical information and video information by means of passive electro-optical display media such as, for example, liquid crystals, electrophoretic suspensions and electrochromic materials.

A display device of the type described in the opening paragraph is known from Netherlands publication no. 8701420 (PHN 12.154) in the name of the Applicant. In a display device shown in this publication the pixels are given a defined value for each row because the capacitances associated with these pixels are accurately charged or discharged after they have been discharged or charged too far (either or not accurately). To this end such a picture display device is provided with means for applying, prior to selection, an auxiliary voltage across the pixels, which voltage is beyond or on the edge of the voltage range to be used for picture display.

In other display devices the pixels are driven *via* MIMs or thin-film transistors whose gate electrodes are connected to selection rows and whose source electrodes are connected to data rows.

Notably in liquid crystal display devices the capacitance associated with a pixel may vary with the drive voltage; this may detrimentally influence the response time. This influence can be easily demonstrated by way of an example.

A display element or picture cell (pixel) has, for example, a capacitance C_I at a drive voltage V_I. When the pixel is driven with a voltage V_J in an address or selection period, the total charge on the pixel will be C_IV_J, while the pixel will tend to adjust itself at the capacitance C_J associated with the voltage V_J, *inter alia*, because the liquid crystal material is oriented differently. Due to charge preservation the voltage and the capacitance of the pixel will settle at values V_K and C_K in the non-selection period, for which it holds that $V_K.C_K = C_I.C_J$. In other words, the value V_J to be impressed is usually not reached and when the data remain the same, the pixel will have to be driven at least once more the value V_J, which leads to a delayed response.

Another source which leads to an erroneous first adjustment and hence a delayed response in a picture display device using active drive is the so-called DC offset voltage which occurs when using the drive mode in accordance with NL-A-8,701,420, but also when using other drive modes such as, for example, the drive mode using thin-film transistors.

One of the objects of the present invention is to eliminate the above-mentioned drawbacks as much as possible. It is a further object of the invention to provide a display device having a fast response and minimal or no "image retention", and to provide a method of manufacturing such display devices and apparatus to be used for their manufacture.

It is based, *inter alia*, on the recognition that variations of the voltage across a pixel caused by voltage-dependent capacitances in the pixel can be taken into account in advance.

To this end a display device according to the invention is characterized in that it is provided with correction means which define the column voltages, dependent on externally applied signals.

In this way the pixels are submitted to a pre-adapted drive voltage which at least substantially prevents the above-described delay.

In this case the correction means can be adapted in such a way that they correct for a pixel capacitance which varies with the voltage-adjustment at the transmission/voltage characteristic.

On the other hand they can correct for an externally caused variation of the voltage-adjustment at the transmission/voltage characteristic such as, for example, the variation caused by capacitances of the drive element.

A combination is alternatively possible.

Generally, the column voltage to be used in a display device after correction is defined by:

$$V_c = \frac{C.(V').V'}{C(V)}$$

in which

V : previous column voltage across the pixel,

V': desired column voltage across the pixel,

and in which

C(V) : the capacitance of the pixel depen-

dent on the column voltage.

The correction stated above can be performed, for example, directly by means of a microprocessor, but this is usually rather cumbersome. It is therefore preferred to use a look-up table in which the digitally coded voltages V, V' generate an address. In a (video) signal of 8 bits this would lead to a 16-bit address, in other words, a RAM or ROM for the look-up table of 64 K correction values. However, in practice it is sufficient to use an addressing accuracy of 12-14 bits so that it is sufficient to use 4K-16K memory sites for correction values. Said RAM, ROM or microprocessor may be present as a separate unit, but it may alternatively form part of a larger memory or drive system which is already present for, for example, signal processing.

Moreover, during selection of a pixel an offset voltage which is also defined by the capacitance of the pixel can be generated across the pixel with a value of:

$$V_{off} = \frac{V_R C_X}{C_X + C_{LC}}$$

(V_R: amplitude of selection pulse during falling edge,

C_X: capacitance of drive element, for example, the gate-drain capacitance of a thin-film transistor or the capacitance associated with a diode or MIM (metal-isolator-metal),

C_{LC}: voltage-dependent capacitance of the liquid crystal). As a result, the voltage across the pixels acquires a value which differs from the externally applied signal voltage.

Since both C_X and C_{LC} may be voltage-dependent, a correction can be defined in the same way as described above for the drive voltage of a pixel. This correction can be performed for one of the capacitances C_X, C_{LC} separately, or combined for both.

If the external signal differs little from the signal presented during the previous selection period, the correction will usually be small enough to be performed completely within one picture period. In the case of larger differences it may be advantageous to use, as it were, an overcompensation because of the inertia of the pixel and because a larger directing force must be exerted on the liquid crystal molecules. A device according to the invention, in which this is realised, is characterized in that the correction means perform an extra correction at a difference between an externally applied signal and the (column) voltage applied during a previous selection period, which difference is larger than a predetermined threshold value.

A method of manufacturing a display device according to the invention is characterized in that during manufacture at least a part of the drive unit is adjusted in such a way that, dependent on applied signals, the drive unit gives the electrodes such drive voltages that a deviation of the transmission level of a pixel due to a voltage-dependent behaviour of the pixel is at least partly compensated for.

The invention will now be described in greater detail with reference to some embodiments and the drawings in which

Fig. 1 shows diagrammatically a display device according to the invention;

Fig. 2 shows diagrammatically several correction possibilities;

Fig. 3 shows the drive of a pixel *via* a thin-film transistor;

Fig. 4 shows the associated drive signals and voltages across the pixel,

and

Figs. 5 and 6 show some forms of correction possibilities according to the invention.

The Figures are diagrammatic; corresponding components are generally denoted by the same reference numerals.

The display device of Fig. 1 comprises a plurality of pixels 4, for example, liquid crystal pixels arranged in rows and columns. These pixels are driven *via* switching elements 5, for example, diodes or MIMs (metal-isolator-metal) and are arranged in a matrix configuration. Information present at the column electrodes 3 is presented to the pixels 4 by successively selecting (energizing) row electrodes 2. Row electrodes 2 are successively selected by means of, for example, a shift register 6, while the information to be presented for a selected row of pixels is stored in a register 7.

An incoming video signal 10 may be directly connected to the register 7 for this purpose. The voltages at the column electrodes 3 are then equal to the presented video voltages for each pixel. Dependent on the drive mode, the switching elements 5 used in the matrix (diodes, MIMs, TFTs), the column voltages and the selection voltages at the row electrodes 2, which voltages originate from the shift register 6, a pixel 4 is subjected to a voltage V_I during selection. The liquid crystalline material which is used for the pixels has a given voltage-dependent dielectric constant. The capacitance of a pixel is therefore voltage-dependent and a given capacitance C_I is associated with the voltage V_I. If the voltage is V_J in a subsequent frame or field period during selection, the pixel acquires a charge $C_I V_J$ during selection. Due to charge preservation the voltage across the pixel changes during non-selection to a value V_K, for which it holds that: $V_K C_K = C_I V_J$ (possible charge losses due to,

for example, leakage currents have not been taken into account in this case). The pixel thus does not immediately acquire the desired voltage V_J (and the associated capacitance C_J), which becomes manifest in a delayed response.

According to the invention this can be prevented by giving the data or column voltages a corrected voltage V_c in advance, for which it holds that:

$$V_c = \frac{V_d C_d}{C(V)}$$

so that the pixel acquires a charge $C_l V_c = V_d C_d$ which corresponds to the desired adjustment.

More generally:

$$V_c = \frac{C(V').V'}{C(V)}$$

in which:

- C(V): voltage-dependent capacitance of the pixel;
- V: previous column voltage (or voltage across the pixel);
- V': desired column voltage (or voltage across the pixel).

Fig. 1 shows a device with which the above-described voltage V_c can be generated.

The incoming video signal 10 is converted by means of an A/D converter 11 into digital signals of, for example, 8 bits which are stored in a first memory 13 *via* a first switch 12. Dependent on the mode of operating the display device during a previous frame or field period, a second memory 14 is charged with the associated video information. The previous field here means the previous field of the same kind (odd or even). When one of the rows is selected (row electrodes 2), the digital information associated with this row is passed on for each column 3 from the memories 13, 14 to an address circuit 19 (for example, an address register) *via* the switches 15, 16. The drive circuit 22, which receives a synchronizing signal 23, ensures the mutual synchronization of the different switches, registers, memories, etc. *via* drive lines 24.

The position of the switches 15, 16 is such that the 8 bits from the first memory 13 constitute the most significant part of the address in the address circuit 19 which drives a look-up table 20. The least significant address bits are constituted by the m most significant bits from the second memory 14. The reference m indicates, for example, a value of between 4 and 8. At m = 4 it is sufficient to use a memory capacity of the look-up table 20 of 4 k memory sites, while nevertheless obtaining a satisfactory correction.

The look-up table 20, which comprises, for example, a ROM or RAM, is programmed in such a way that a corrected drive value defined by the above-mentioned formula is passed on (in a digital form) to the D/A converter 21. The corrected column voltages converted to analog values are then loaded into the register 7.

Dependent on the drive mode, a second memory 14 is loaded with video information during a subsequent frame or field period by changing over switch 12. When the rows 2 are being read, the switches 15, 16, 17, 18 are changed over. The most significant part of the address in the address circuit 19 now comes from the second memory 14 *via* switch 18, while the least significant part comes from the first memory 13 *via* switch 17, in which memory video information has been stored during a previous frame (field) period. Data voltages which are largely corrected for capacitance variations of the electro-optical material (liquid crystal material) in accordance with the previously mentioned formula are thus presented to the column electrodes 3 *via* the look-up table 20 and the D/A converter 21. This compensation will lead to a faster response, notably at larger variations of the voltage across a pixel.

Fig. 2 shows by way of example how the corrected voltage V_c may vary (line a) as a function of the difference between a voltage (V') presented for a given pixel and the voltage for the same pixel during a previous selection (V). The relation shown in Fig. 2 can be realised by means of the look-up table 20, but also, for example, by means of a microprocessor.

The rate at which the liquid crystal molecules assume a different orientation upon voltage variations may still be too slow at larger voltage variations (for example, due to too weak reorientation forces). Consequently, the desired transmission value is not immediately reached in the first selection period, even if the above-mentioned correction is used. In that case a correction which, as it were, is too large may be performed for large deviations between a previous column voltage V and a desired column voltage V'. The correction voltage which is dependent on (V'-V) is then defined, for example, by means of a relation which is partly illustrated by means of broken lines (line b). This correction can be implemented by means of a look-up table 20. At larger values of (V'-V) there is, as it were, overcompensation, while the original compensation is maintained at smaller values.

Fig. 3 shows diagrammatically a pixel 4 which is driven by a thin-film transistor 25 and which forms part of a dislay device arranged in a matrix

configuration comparable with that of Fig. 1. A row electrode 2 is connected to the gate electrode 26 of the transistor 25, while the column electrode 3 is connected to the source contact 27. The drain contact 28 is connected to the pixel 4 which has a voltage-dependent capacitance (C_{LC}). The capacitance 29 represents a capacitance C_X associated with the transistor 25 (channel capacitance, gate-drain capacitance). Due to capacitive coupling this capacitance produces an offset voltage across the pixel with a value of:

$$V_{off} = \frac{V_R.C_X}{C_X+C_{LC}}$$

at the falling edge of a selection pulse 30 (Fig. 4a) on the row electrode 2. (V_R: amplitude selection pulse, falling edge). Since C_{LC} is voltage-dependent again (and is thus a function of the voltage across the pixel), V_{off} is also voltage-dependent. A high capacitance C_{LC} leads, for example, to a response on the pixel as is illustrated by means of curve a in Fig. 4b, whereas a lower value gives rise to curve b. The voltage drop V_{off} across the pixel can be compensated again by employing a correction compensating for this voltage drop, dependent on the applied drive voltages.

To this end the external signal 10 is again applied to an A/D converter 11 (Fig. 5). It addresses a look-up table 20 whose output supplies a (digitized) corrected voltage value and which, if desired, also is corrected for voltage dependency of C_X. A correction voltage 31 is obtained *via* a D/A converter 21. The normally processed signal 32 from the processor 34 is added to the correction voltage by means of the circuit 33 which applies the correct voltage to the column electrodes 3.

Similarly, corrections can be performed for matrices which are driven with diodes or MIMs.

This correction may of course also be combined with that described with reference to Figs. 1, 2.

The correction may also be based on a weighted average of the digital values of the voltages V' and V, in which, for example, V is multiplied by a factor k in the circuit 33 and subsequently the (digitized) voltages V' and kV are added in an address register 19 of the look-up table 20.

To program a look-up table 20, for example, the voltage dependence of the liquid crystal capacitance is determined first. The correction which must be stored in the look-up table (RAM or ROM) is calculated with reference to the formula:

$$V_c = \frac{C(V').V'}{C(V)}$$

A device for adjusting the look-up table comprises means for programming a RAM or ROM, for example, in accordance with a correction curve in Fig. 2, either or not using overcompensation, or in accordance with the formula:

$$V_{off} = \frac{V_R.C_X}{C_X+C_{LC}}$$

if there is only a correction for the voltage drop at the end of a selection pulse. In that case V_R and C_X must also be known. The two corrections can of course also be provided jointly in a look-up table in the form of a ROM or RAM. The device need not exclusively comprise programming means but it may be simultaneously equipped with apparatus for measuring the capacitance of electro-optical materials (particularly liquid crystal material) or with ready-made matrix panels. Measuring and adjusting may then be coupled directly.

The invention is of course not limited to the embodiments shown, but it is also applicable to other drive modes, such as, for example, a drive matrix based on plasma addressing or addressing by means of an electron beam.

Claims

1. A display device comprising an electro-optical medium between two supporting plates, provided with a system of pixels arranged in rows and columns, provided with means for providing row and column connections during operations with such voltages that column connections are provided with column voltages during at least a part of a selection period in which rows are selected *via* drive elements, characterized in that the device is provided with correction means which define the column voltages, dependent on externally applied signals.

2. A display device as claimed in Claim 1, characterized in that the correction means correct for a pixel capacitance which varies with the adjustment at the transmission/voltage characteristic.

3. A display device as claimed in Claim 1, characterized in that the correction means correct for an externally caused variation of the adjustment at the transmission/voltage characteristic.

4. A display device as claimed in Claim 3, characterized in that the correction means correct for variations caused by capacitances of the drive element.

5. A display device comprising at least one pixel with an electro-optical medium between electrodes defining the pixel, and a drive unit for applying drive voltages to the electrodes, characterized in that the device is provided with correction means correcting the drive voltages at the electrodes dependent on externally applied signals and on the voltage-dependent behaviour of the pixel.

6. A display device as claimed in any one of the preceding Claims, characterized in that the correction means perform an extra correction at a difference between an externally applied signal and the signal applied during a previous selection period, which difference is larger than a predetermined value.

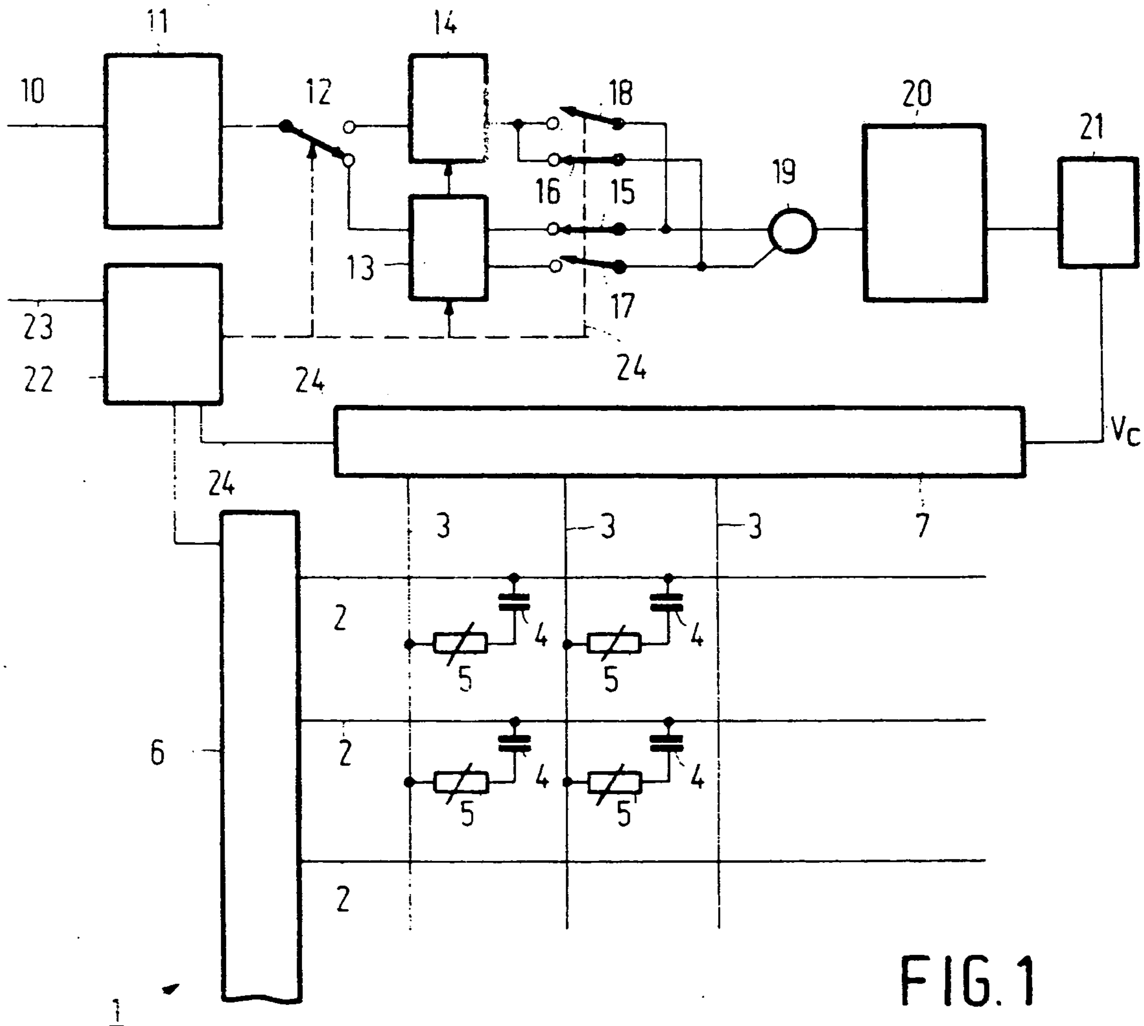
7. A display device as claimed in any one of Claims 1 to 6, characterized in that the correction means comprise a look-up table.

8. A method of manufacturing a display device comprising a system of pixels with an electro-optical medium between electrodes defining pixels, and a drive unit for applying drive voltages to the electrodes, characterized in that during manufacture at least a part of the drive unit is adjusted in such a way that, dependent on applied signals, the drive unit gives the electrodes such drive voltages that a deviation of the transmission level of a pixel due to a voltage-dependent behaviour of the pixel is at least partly compensated for.

9. A method as claimed in Claim 8, characterized in that the capacitance/voltage characteristic of a pixel is defined and a correction voltage is defined at a given input signal, and in that the drive unit is adjusted in such a way that it supplies a correction voltage as a response to the input signal, which correction voltage entirely or partly defines the drive voltage at the electrodes.

10. A method as claimed in Claim 8, characterized in that the drive unit comprises a look-up table which is addressed by the input signal and supplies a corrected drive voltage as an output signal.

11. A device for adjusting a drive unit for use in a method as claimed in Claims 8 to 10, characterized in that, dependent on an electro-optical medium to be used, the device adjusts the drive unit in such a way that it supplies a corrected drive voltage at a given input signal.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Vc
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5
2
1

FIG.1

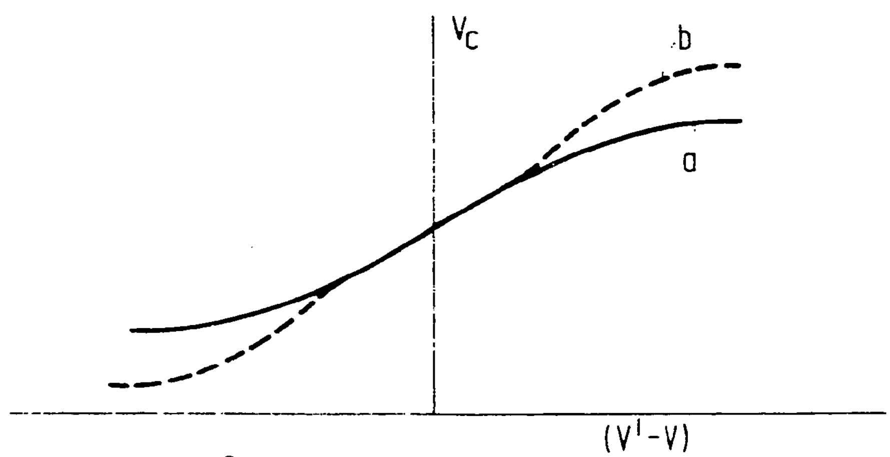
Vc
b
a
(V'-V)

FIG.2

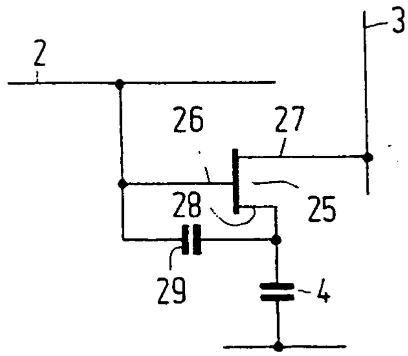

FIG.3

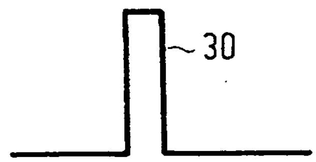

FIG.4a

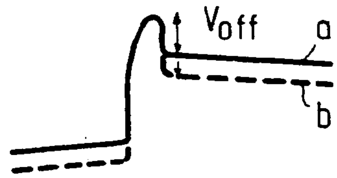

FIG.4b

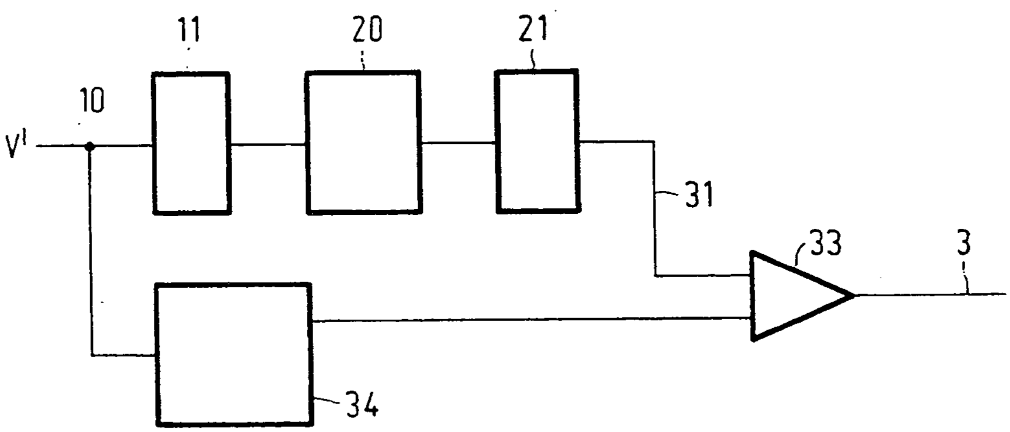

FIG.5

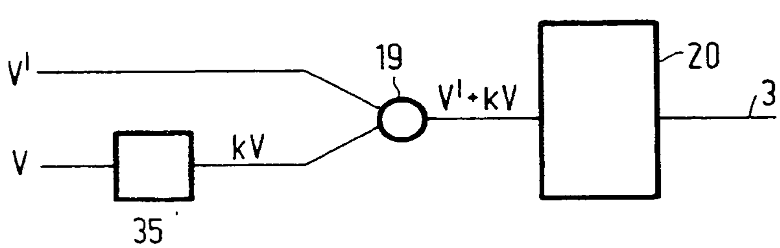

FIG.6

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EUROPEAN SEARCH REPORT

Application Number

EP 91 20 2926

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
X	EP-A-0 196 889 (KABUSHIKI KAISHA TOSHIBA) * abstract; figures 1,5 * * page 4, line 10 - page 6, line 14 * * page 6, line 25 - page 7, line 29 * * page 12, line 8 - page 13, line 5 * ---	1	G09G3/36
A	EP-A-0 229 716 (RCA CORPORATION) * abstract; figure 1 * * column 3, line 53 - column 3, line 65 * ---	1-3,5,8	
A	EP-A-0 381 429 (SHARP KABUSHIKI KAISHA) * abstract; figure 1 * -----	1,6	

TECHNICAL FIELDS SEARCHED (Int. Cl.5)

G09G

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	10 FEBRUARY 1992	VAN ROOST L.L.A.

CATEGORY OF CITED DOCUMENTS

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